UNDERSEA WARFARE RESEARCH CENTER REFLECTS RESEARCH FROM A VARIETY OF DISCIPLINES

The Undersea Warfare (USW) Research Center was established at the Naval Postgraduate School (NPS) in April 2002. The primary objectives of the USW Research Center are to: 1) provide outstanding support for U. S. Navy needs in USW education and research, and 2) make NPS a nationally recognized institution for USW education and research.

The USW Research Center expects to play a valuable role in support of the Navy Sea Power 21 concept and associated transformation capabilities. The appropriate focus will be in support of the Sea Shield portion of Sea Power 21. The Center will provide expertise and focused research efforts, in collaboration with Commander Third Fleet, which supports Sea Trial experimentation associated with Sea Shield capabilities and transformation. The Center will work closely with the USW Academic Committee by providing meaningful USW research opportunities to cement and transform the education skills acquired by NPS students into officer graduate capabilities that provide expert leadership in acquiring the Sea Shield transformation so vital to our Navy and national interests.

Another important component of Sea Power 21 is FORCEnet. The USW Research Center will also contribute significantly to FORCEnet. In a recent letter of appreciation from ADM James R. Hogg, USN (Ret.), Director of the CNO's Strategic Studies Group, he states, "Your insights in the area of acoustical communications were quite valuable in conceiving the seabed-to-space multi-tiered sensor field in FORCEnet. Your work demonstrates an excellent model for an underwater sensor field and wireless network, and helped answer some of the challenges of networking in such a difficult medium."

The Chair of Undersea Warfare, which was established by a Memorandum of Understanding between NPS and the Naval Undersea Warfare Center, will be dual-hatted as the Center Director. The USW Chair is expected to report in March 2002. The selection process is currently underway. The incumbent Chair of Mine Warfare (MIW), **RADM John D. Pearson, USN (Ret.)**, will be dual-hatted as the USW Center's Assistant Director, and is presently serving as the Center Interim Director. NPS faculty members of the Center are all involved in important USW research in submarine warfare, antisubmarine warfare, and/or mine warfare.

NPS USW research reflects a wide variety of NPS disciplines, including Operations Research, Physics, Electrical and Computer Engineering (Signal Processing), Oceanography, Mechanical Engineering (Robotics), and C4I (Common Undersea Picture and Underwater Communications/links to surface and above water nodes). The Center's research activities are supported by reimbursable research funding from external research sponsors.

--continued on page 9

UNDERSEA WARFARE CENTER MEMBERSHIP

Associate Professor Steve Baker (Physics)
Associate Professor Mary Batteen (Oceanography)
Associate Professor Don Brutzman (Information Science)
Professor Peter Chu (Oceanography)
Professor Curt Collins (Oceanography)
Professor Jim Eagle (Operations Research)
Distinguished Professor Donald Gaver (Operations Research)
Professor Anthony Healey (Mechanical Engineering)
CDR John Joseph, USN (Oceanography)
Ms. Michaele Huygen (Library)
Professor Patricia Jacobs (Operations Research)
CDR Daphne Kapolka, USN (Physics)
Associate Professor Andres Larraza (Physics)
Research Professor Tom Muir (Physics)
CDR Art Parsons, USN (Oceanography)
RADM John Pearson, USN (Ret.) (Mine Warfare Chair)
Research Associate Professor Steven Pilnick (Meyer Institute of Systems Engineering)
Joe Rice (Engineering Acoustics Chair)
Associate Professor Jim Sanders (Physics)
Distinguished Professor Turgut Sarpkaya (Mechanical Engineering)
Professor Clyde Scandrett (Applied Mathematics)
Professor Young Shin (Mechanical Engineering)
Associate Professor Kevin Smith (Physics)
Professor Alan Washburn (Operations Research)
Professor Larry Ziomek (Electrical and Computer Engineering)

UNDERSEA WARFARE RESEARCH CENTER, *continued from page 8*

The USW Center provides three primary functions:

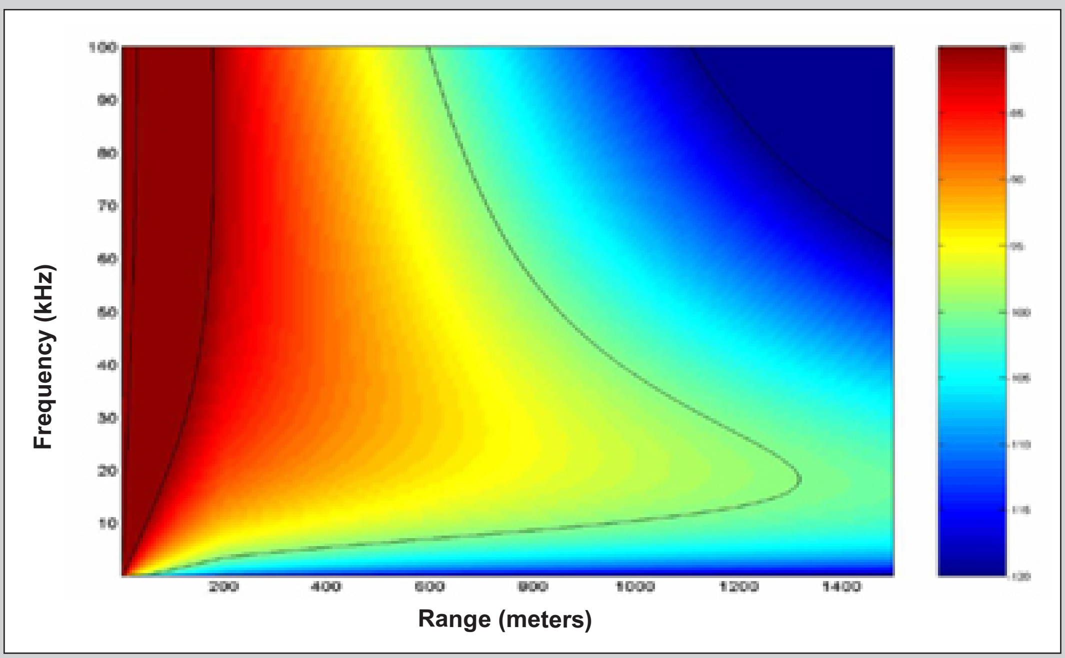
- Research Planning
  - Identification (internally and externally) of thesis topics, professors/advisors, and students,
  - Preparation of research proposals and coordination with potential external sponsors for funding of proposals,
  - Continuing solicitation, from external sponsors, of research topics of interest.
- Research Execution
  - Approve allocation and expenditure of funds for support of research programs,
  - Coordinate with principal investigators/faculty for execution of research programs,
  - Identify/propose solutions for problems encountered in the conduct of research programs.
- Research Database/Records
  - Bibliography of NPS USW research,
  - Bibliography of USW research documents produced outside NPS,
  - Bibliography of external sponsor research topics of interest.

--continued on page 10

LINK BUDGET ANALYSIS FOR UNDERSEA ACOUSTIC SIGNALING

LT Joseph T. Hansen, United States Navy
Master of Science in Engineering Acoustics – June 2002
Advisors: Joseph A. Rice, Engineering Acoustics Chair, and Associate Professor Kevin B. Smith, Department of Physics

Link-budget analysis is commonly applied to satellite and wireless communications for estimating signal-to-noise ratio (SNR) at the receiver. Link-budget analysis considers transmitter power, transmitter antenna gain, channel losses, channel noise, and receiver antenna gain. For underwater signaling, the terms of the sonar equation readily translate to a formulation of the link budget. However, the strong frequency dependence of underwater acoustic propagation requires special consideration, and is represented as an intermediate result called the channel SNR. The channel SNR includes ambient-noise and transmission-loss components. Several acoustic communication and navigation problems are addressed through wideband link-budget analyses.



Signal-to-noise ratio (SNR) of an undersea acoustic channel is strongly dependent on range and frequency as shown in this representative plot. Experimental Seaweb wide-area undersea networks for autonomous sensors and Unmanned Underwater Vehicles (UUVs) are using the 9-22 kHz band, and Seaweb local area networks will use the 30-100kHz band. Frequencies above 100kHz are useful for high-bandwidth acoustic data telemetry at short ranges.

UNDERSEA WARFARE RESEARCH CENTER, *continued from page 9*

The USW Research Center is providing an integrated, comprehensive USW research program at NPS, based on strong leadership and USW credentials with significant, continuing value to USW research sponsors. This program provides a highly significant opportunity for meaningful thesis work for NPS officer students. A complete bibliography of publications and research documents in these areas is available at http://library.nps.navy.mil/home/bibs/submarine/ and http://library.nps.navy.mil/home/bibs/seamines/.

--continued on page 11

HYDRODYNAMICS OF MINE IMPACT BURIAL

LCDR Ashley D. Evans, United States Navy
Master of Science in Meteorology and Physical Oceanography – September 2002
Advisors: Professor Peter C. Chu, Department of Oceanography, and Peter Fleischer, Naval Oceanographic Office, Stennis Space Center

A general physics based hydrodynamic flow model is developed that predicts the three-dimensional six degrees of freedom free fall time history of a circular cylinder through the water column to impact with an unspecified bottom. Accurate vertical impact velocity and impact angle parameters are required inputs to subsequent portions of any Impact Mine Burial Model. The model vertical impact velocity and impact angles are compared with experimental data, vertical impact velocities and impact angle to validate the model mechanics and accuracy. The three dimensional model results are compared through the experimental data with IMPACT28 vertical impact velocities and impact angle. Results indicate the three dimensional model mechanics are sound and marginal improvements are obtained in predicted vertical velocities. No improvement is gained using the three-dimensional model over IMPACT28 to predict impact angle. The observed stochastic nature of mine movement in experimental data suggests this three dimensional model be used to model the hydrodynamic flow phase in a statistical mine burial model that provides distributions for input parameters and domain characteristics, and present a probabilistic output for development of a relevant navy tactical decision aid.

Equipment developed for the 1/15 scale mine drop experiment in the NPS swimming pool in July 2001. Here 'A' denotes drop angle device, 'B' is the mine injector, 'C' is the infrared light sensor, 'D' is output to the universal counter, and 'E' is mine shapes.

UNDERSEA WARFARE RESEARCH CENTER, *continued from page 10*

Recent theses of USW research of interest, in submarine warfare, antisubmarine warfare, and mine warfare include:

The Influence of Shallow Water Variability on Short Range Water-Bourne Propagation, **LT Stephen C. Karpi, USN** (December 2002)

Direct-sequence Spread-spectrum Modulation for Utility Packet Transmission in Underwater Acoustic Communication Networks, **LCDR Peter S. Duke, Canadian Navy** (September 2002)

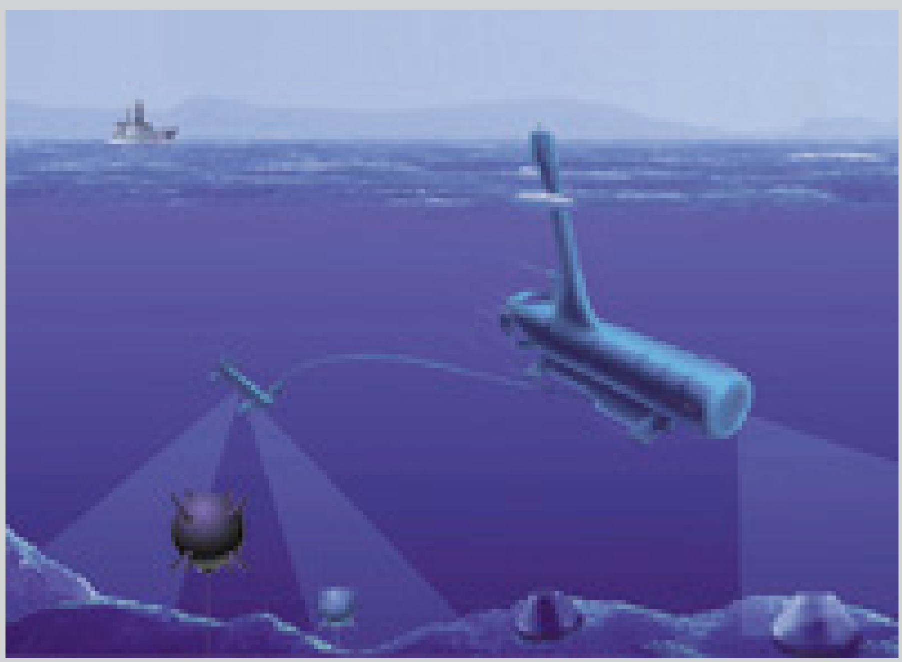
Link Budget Analysis for Undersea Acoustic Signaling, **LT Joseph T. Hansen, USN** (June 2002)

--continued on page 42

THE EFFECT OF SENSOR PERFORMANCE ON SAFE MINEFIELD TRANSIT

LT Chihoon Kim, Republic of Korea Navy
Master of Science in Operations Research – December 2002
Advisors: Research Associate Professor Steven E. Pilnick, Meyer Institute of Systems Engineering, Professor Patricia A. Jacobs, Department of Operations Research, and Distinguished Professor Donald P. Gaver, Department of Operations Research

Mines are relatively cheap weapons that can be employed in significant quantity by any country with even a modest military budget, and can be very effective at severely damaging or sinking ships or denying maritime access to an area. In this thesis, simulation and analytical models are formulated and studied to investigate the benefits and risks of mine avoidance, without object classification capability, under circumstances that include imperfect sensors and false targets. Two models of mine avoidance maneuvering are formulated, with increasing complexity in both their analytical and simulation implementations. With both formulations, results are obtained and analyzed to produce tables showing the probability of successful minefield transit as a function of sensor probability of detection vs. density of mine and non-mine, mine-like bottom objects, and the false alarm rate. The tables show the range of those parameter values for which mine avoidance maneuvering improves the probability of safe transit, and the values for which mine avoidance maneuvering reduces the probability of safe transit. The decrease is attributable to the fact that mine avoidance maneuvering increases the distance traveled in the minefield and the consequent risk of damage or destruction by an undetected mine. Quantitative results for the increased distance traveled in the minefield are also presented. Finally, a comparison of the two models of mine avoidance maneuvering show, not surprisingly, that the results of the simpler model are not good approximations of the results obtained with the more complex model, suggesting that even greater complexity in maneuver modeling may be desirable for some purposes.



The Remote Mine-hunting System (RMS), under development by the Navy, is an example of a system that may be used for the tactics of mine-avoidance.

UNDERSEA WARFARE RESEARCH CENTER, *continued from page 11*

Environmental Influence on Shallow Water Bottom Reverberation, **Major Boon Chuan Lee, Singapore Navy** (March 2002)

Numerical Analysis of Bottom Reverberation and the Influence of Density Fluctuations, **LT Han Kao, Republic of China Navy** (December 2001)

The Effect of Sensor Performance on Safe Minefield Transit, **LT Chihoon Kim, Republic of Korean Navy** (December 2002)

Hydrodynamics of Mine Impact Burial, **LCDR Ashley D. Evans, USN** (September 2002)

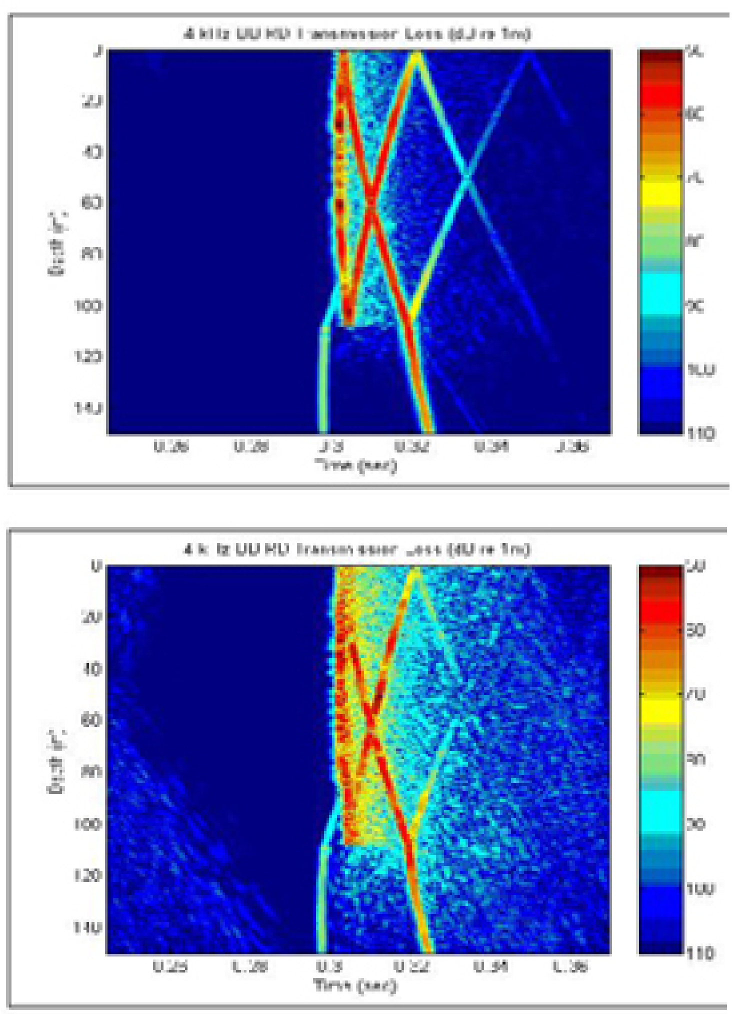
A Minefield Reconnaissance Simulator, **Mauricio Jose Machado Guede, Brazilian Navy** (June 2002)

--continued on page 43

THE INFLUENCE OF SHALLOW WATER VARIABILITY ON SHORT RANGE WATER BOURNE PROPAGATION

LT Stephen C. Karpi, United States Navy
Master of Science in Engineering Acoustics – December 2002
Advisors: Associate Professor Kevin B. Smith, Department of Physics, and Peter H. Dahl, Applied Physics Laboratory, University of Washington

Interest in enhancing the forecasting capabilities of both active and passive sonar systems employed in littoral regions has greatly escalated over the past 10 years. This requires a need for improvements in the general understanding of the influence of shallow water variability on acoustic propagation. This work examines the influence on the relatively short-range water-bourne propagation paths of shallow water variability. Both internal wave fluctuations and random sound speed perturbations will be considered The effects of littoral variability on acoustic propagation will be quantified in terms of spatial (vertical) coherence functions. Since the effects of the water-column variability are of interest, the direct water-bourne propagation path will be solely analyzed. The data to be examined will be generated numerically based on an acoustic propagation model employing environmental data taken from the East China Sea as part of the Office of Naval Research-sponsored ASIAEX experiments.



Predictions of broadband (2msec 4kHz pulse) acoustic propagation in shallow water with turbulent-like sound speed perturbations. The ocean bottom is at 110m. The root-mean-square level of the perturbation (upper panel) is 1m/s, and (lower panel) 5m/s. Note how the increase in perturbation level enhances the breakdown of wavefront coherence.

UNDERSEA WARFARE RESEARCH CENTER, *continued from page 42*

Range Dependent Mine Hunting Using CASS-GRAB Model, **LT Nick A. Vares, USN** (June 2002)

Transmitting Beam Patterns of the Atlantic Bottlenose Dolphin: Investigations in the Existence and Use of High Frequency Components Found in Ecolocation Signals, **LT Tobias J. Lemerande, USN** (June 2002).

BEDFORM EVOLUTION UNDER THE COMBINED INFLUENCES OF WAVES AND CURRENTS AT THE INNER-SHELF MISO SITE

ENS William C. Blodgett, Jr., United States Navy
Master of Science in Physical Oceanography – June 2002
Advisors: Research Professor Timothy Stanton and Distinguished Professor Edward B. Thornton, Department of Oceanography

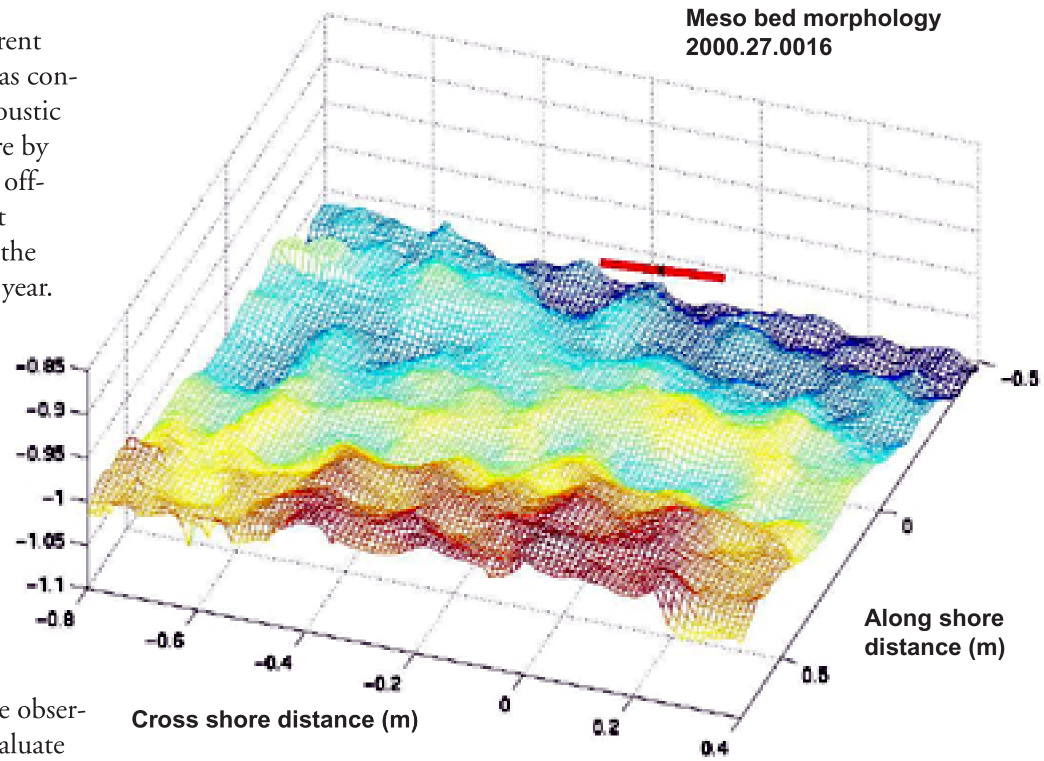
Observations of the temporal evolution of waves, currents, and bed response data collected by an instrumented frame deployed in 12m of water at the Monterey Inner Shelf Observatory (MISO) off the coast of Monterey, California are analyzed in terms of measured wave and current forcing statistics and ripple geometry. During the year 2000, a Broadband Acoustic Doppler Current Profiler (BADCP)

--continued on page 44

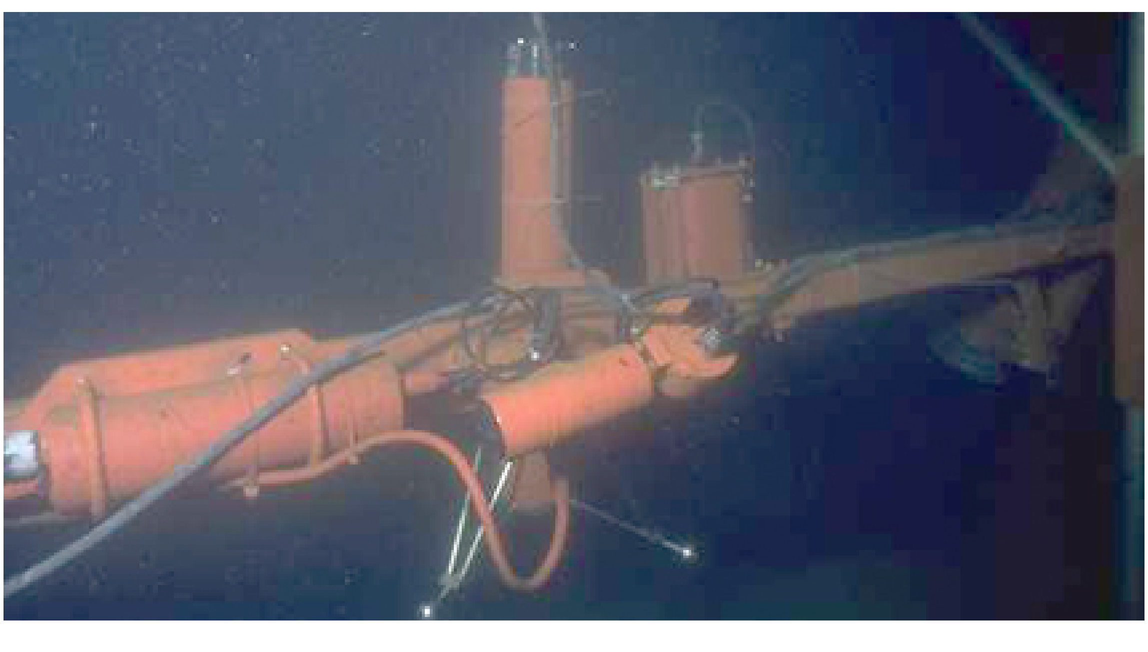
The Monterey Inner Shelf Observatory (MISO) off the coast of Monterey, California.

BEDFORM EVOLUTION UNDER THE COMBINED INFLUENCES OF WAVES AND CURRENTS AT THE INNER-SHELF MISO SITE, *continued from page 43*

collected continuous wave and current measurements. Bed morphology was continually mapped by a Scanning Acoustic Altimeter (SAA) in a 1m alongshore by 1.5m cross-shore area immediately offshore from the MISO frame. Relict ripples were observed to dominate the bedforms throughout much of the year. Ripple growth in the alongshore direction was observed during conditions of marginally critical flow as defined by the critical combined wave and current Shields parameter. As flow conditions increased above the critical level, ripple growth in the alongshore direction ceased, and cross-shore wavelengths began to grow and dominate. Together, these observations and data sets are used to evaluate the applicability of existing ripple prediction algorithms. Altogether, five models are tested, and it was concluded that they could not independently predict the bed's response.



Bedform evolution under the combined influence of waves and currents at the Inner Shelf MISO site (above).



MISO instrument frame deployed off-shore in Monterey Bay. It is cabled to shore with fiber optic data and shore power links allowing long timeseries of wave forcing and bed response to be measured over seasonal timescales. The photo specifically shows the scanned acoustic altimeter in the foreground that maps a 2-meter square of the sandy bed three times an hour, and the bistatic coherent profiler that measures velocity and turbulence profiles above the bed. Both instruments were developed at NPS (left).